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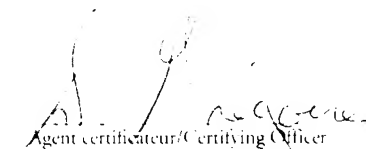
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Specification and Drawings, as originally filed, with Application for Patent Serial No:
2,325,643, on November 10, 2000, by **GROUPE LYSAC INC./LYSAC GROUP INC.**,
assignee of Claude Couture, David Bergeron and Frédéric Picard, for "Crosslinked
Polysaccharide, Obtained by Crosslinking with Substituted Polyethylene Glycol, as
Superabsorbent".


Agent certificateur/Certifying Officer

November 7, 2001

Date

Canada

(CIPO 68)
01-12-00

OPIC  CIPO

ABSTRACT

5 New reticulated polysaccharides obtained from polysaccharides by crosslinking with at least one crosslinker selected in the group constituted by substituted (preferably halogenosubstituted, more preferably substituted by Br, Cl or I) polyethyleneglycols, useful as superabsorbent alone or in a mixture.

**CROSSLINKED POLYSACCHARIDE, OBTAINED BY CROSSLINKING
WITH SUBSTITUTED POLYETHYLENE GLYCOL, AS
SUPERABSORBENT**

5 The present invention relates to new reticulated polysaccharides obtained from polysaccharides by crosslinking with at least one crosslinker selected in the group constituted by substituted (preferably halogenosubstituted, more preferably substituted by Br, Cl or I) polyethyleneglycols.

10 The present invention also relates to processes for preparing said crosslinked polysaccharides.

 The present invention also relates to the use of the crosslinked polysaccharides of the invention as superabsorbents, more particularly as inexpensive and/or
15 hypoallergenic biodegradable superabsorbents.

 The invention also relates to superabsorbents mixtures comprising at least one of crosslinked polysaccharides of the invention.

20 BACKGROUND OF THE INVENTION

Anbergen and Oppermann¹ have studied the elasticity and the swelling behaviour of sodium carboxymethylcellulose and hydroxyethylcellulose, chemically crosslinked with divinylsulfone 1.

5 In a patent issued in 1995, Kabra² reported the sorption capacity of hydroxypropylcellulose, crosslinked with different concentration of divinylsulfone (from 0.28 to 2.98 weight %). His best result showed a water sorption capacity of 44 g/g with a crosslink of 0.91 weight %. The author also mentions that other hydrophobically modified carbohydrate polymers can be chosen, such as hydroxypropylstarch.

10 More recently, a patent has been granted to SCA Hygiene Products AB³ which extends the study with divinylsulfone to low-cost, readily available, renewable starting materials such as carboxymethylcellulose, carboxymethylstarch, and others. According to the authors, results may be obtained with a mixture of carboxymethylcellulose:
15 hydroxyethylcellulose (3 : 1) which absorbs close to 95 g of synthetic urine per g of polymer after free swelling for 120 min. In this patent, however, the quantity of divinylsulfone used is not reported. The same company has extended their work with divinylsulfone to other polysaccharides containing acidic groups⁴. It appears that the best result was obtained with carboxymethylcellulose crosslinked with 14 mol% of
20 divinylsulfone. This results in a centrifugal retention capacity of 111 g/g with synthetic urine. On page 6 of the patent⁴, it mentioned that the superabsorbent polysaccharides combine high absorption capacity with control of bacterial growth and control of odour, as well as with biodegradability. There is however no evidence that such compounds

would be biodegradable, particularly since it is well known that carboxymethylcellulose and carboxymethylstarch are not completely biodegradable. Moreover, it appears that the diethylsulfone diether linkage is not biocompatible.

5 Therefore, there is still a need for new polysaccharide-based superabsorbents with a significant biodegradability.

DESCRIPTION OF THE INVENTION

10 The new reticulated polysaccharides according to the invention are obtained by crosslinking of a polysaccharide with at least one substituted polyethylene glycol.

15 A preferred embodiment of the invention is constituted by reticulated starches obtained by crosslinking starches with at least one polyethylene glycol. As a matter of exemplification, starches crosslinked with dichloropolyethylene oxide are preferred particularly since starch is a renewable and inexpensive starting material.

20 The reticulated starches according to the invention are characterized by reticulation occurring at first on the OH group on the C6 carbon atom of the polymeric unit, then on a C2 or C3 carbon atom of the polymeric polysaccharide.

The crosslinker used for preparing the crosslinked starches of the invention is a substituted polyethylene glycol .

Polyethylene glycol (PEG 2.) has been used in blended starches for specific applications
5 ⁵⁻⁹. Starch can react with ethylene glycol in the presence of an acid catalyst at elevated temperature to yield crude mixtures of glycol glucosides by cleavage of glycosidic bonds^{10,11}. By high energy radiation, it is possible to link poly(ethylene oxide) to starch¹². It has also been reported that starch dialdehyde reacts with polyethylene glycol to give an acetal functionality¹³; Ethylene oxide can be grafted to starch by anionic
10 polymerization^{14,15} and polyethylene glycol chloroformate derivative¹⁶ or ethylene glycol chloroformate¹⁷ can also be used to crosslink starch. Moreover, diglycidyl ether ¹⁸, polyglycidyl ethers¹⁹ and ethylene glycol dimethacrylate²⁰ are among known crosslinkers.

15 Polyethylene glycols are biodegradable aerobically and anaerobically²¹.

Starches crosslinked with dichloro polyethylene oxides 3 appear to be biodegradable. The study of the crosslinker length was performed by preparing dichloro derivatives of di 4, tri 5 and tetra ethylene oxide 6 (SOCl₂, pyridine, benzene, reflux).
20 The experimental result thereby obtained show that carboxymethylstarch crosslinked with 0.62% of divinylsulfone 7, gives a water retention of 23 g/g in 0.9% saline solution, compared to 30 g/g when crosslinked with 9.85% of dichlorotriethylene dioxide 8. The starch-citraconic half ester crosslinked with 0.6% of divinylsulfone 9 were found to

exhibit a good water retention (25 g/g). The effect of divinylsulfone and dichlorotriethylene dioxide concentrations on the water retention of crosslinked carboxymethylstarch in 0.9% saline solution, are shown on figures 1 and 2. Even if 15 times more quantity of dichlorotriethylene dioxide is required to reach the maximum water retention, the choice of the former is still advantageous since divinylsulfone is very expensive.

Crosslinked carboxymethylstarches (figures 1 and 2) are prepared in two steps.

Starch is first alkylated with chloroacetic acid, thus the alkylated starch thereby obtained is crosslinked.

The applicant has also discover that it is possible to perform the crosslinking before the alkylation without negative effect on the water retention.

One important aspect is to prepare starch derivatives without starch gelatinisation. This result was achieved with a lower pH with NaOH 3%, lower temperature and by adding sodium chloride solution.

Other polyethylene glycol derivatives may be used as crosslinkers. For instance, other dihalides (Br, I) could be prepared as well as dichloroformates derivatives 10; diacyl chloride derivatives 11 and; diglycidyl derivatives 12. Moreover, carboxymethylstarch could be replaced by maleate 13, succinate 14, 15, citraconic 16,

phthalates half esters 17, sulfate 18, sulfonate 19, phosphate starches 20 and cationic starches 21, 22 as well. Other examples are carboxylate acetal 23, citrate 24, acognitate 25, N,N-dicarboxymethylamine 26, N,N,N-tricarboxymethylammonium 27, citrate 28; the last 3 compounds utilising epichlorohydrin as linker arm; and
5 ethylenediamitetraacetate (EDTA) conjugate 29.

Examples of starches useful as starting materials are: corn, wheat, rice, potato, tapioca, waxy maize, sorghum, sago, waxy sorghum, physically modified starches and non-gelatinized starches. Other polysaccharides can also be used such as cellulose, gums,
10 dextrans, polygalactomannan, and chitosan. In all cases, anionic and cationic functionalizations of the selected polysaccharide could be introduced before or after the crosslinking

Water Retention Unit (WRU)

15 The Water Retention Unit (WRU) has been measured by the following procedure.

Two empty 15 ml test tubes (duplicata) are weighted (T_e). Samples around $0.3g \pm 0.005g$ (S) are introduced into both tubes. Saline solution (10 ml, 0.9%) is added and the
20 gel is vortexed for 1 minute then allowed to stand for 15 minutes. Tubes are centrifuged at 2000RPM for 5 minutes and the upper aqueous layer is decanted at 30° angle for 5 seconds and tubes are weighted again (T_s). In case there is no aqueous layer, the

procedure is repeated with $0.2\text{g} \pm 0.005\text{g}$ samples. WRU is calculated according to the equation (1) and is expressed in g of saline solution per g of absorbent.

5
$$\text{WRU} = \frac{T_s - T_e - S}{S} \quad (1)$$

Those skilled in the art will gain further and better understanding of this invention and the new and important advantages, which is offered from the following illustrative, but not limiting, examples of this invention as it has been carried out.

EXAMPLE 1

Preparation of the crosslinker 1,5-dichloro-3-oxapentane (dichlorodiethylene oxide 4).

15

10.0g (0.094 mol) of diethylene glycol were dissolved in 100 ml benzene. To this solution, 30.8 ml (4eq.) of pyridine were added, followed by a dropwise addition of 27.5 ml (4eq.) of thionylchloride. The reaction mixture was heated at reflux for 24 hours. At room temperature, the organic layer was decanted from the pyridinium hydrochloride salt, washed with 150 ml of water, dried on anhydrous sodium sulfate, filtered and evaporated to dryness to give 8.4g (65% yield) of the dichloride as a light yellow liquid, used without further purification. Infrared spectroscopy showed the absence of hydroxyl band.

20

IR (neat): 2964, 2865, 1450, 1125, 747, 669 cm^{-1} .

5 EXAMPLE 2

Preparation of the cross-linker 1,8-dichloro-3,6-dioxaoctane (dichlorotriethylene dioxide 5).

10 10.0g (0.067 mol) of triethylene glycol were treated as example 1 with 22 ml (4eq.) of pyridine and 19ml (4eq.) of thionylchloride to give 8.8 g (62% yield) of the dichloride as a yellow oil, used without further purification. Infrared spectroscopy showed the absence of hydroxyl band.

IR (neat): 2962, 2870, 1452, 1123, 747, 666 cm^{-1} .

15

EXAMPLE 3

Preparation of the crosslinker 1,11-dichloro-3,6,9-trioxaundecane (dichlorotetraethylene trioxyde 6).

20

10.0g (0.052 mol) of tetraethylene glycol were treated as example 1 with 17 ml (4eq.) of pyridine and 15 ml (4eq.) of thionylchloride to give 7.2g (61% yield) of the dichloride

as a yellow oil, used without further purification. Infrared spectroscopy showed the absence of hydroxyl band.

IR (neat): 2951, 2870, 1459, 1118, 746, 665 cm^{-1} .

5

EXAMPLE 4

Preparation of a carboxymethylstarch, crosslinked with divinylsulfone (0.62%), compound 7.

10

2.0g (0.0123 mol) of wheat starch A (Supercell 1201-C, ADM/Ogilvie) was suspended in 40 ml of deionized water. Under stirring, 3.5 ml 30% NaOH (0.0263 mol, 2.1eq.) was added dropwise and the solution stirred at room temperature for 1 hour. Chloroacetic acid (1.16 g, 0.0123 mol, 1eq), dissolved in 10 ml of deionized water and neutralized with 15 1.6 ml 30% NaOH (0.0123 mol, 1 eq.) was added dropwise and the reaction mixture was heated at 70°C for 24 hours. At room temperature, 12mg (0.62 weight %) of divinylsulfone dissolved in 10ml acetone, was added dropwise and the solution was stirred for 2 hours. The polymer was precipitated with 100 ml of methanol, triturated in a blender, washed with 3 portions of 60 ml methanol, filtered and dry at 60°C for 16 hours 20 to give 1.97g of a white solid. The solid was grinded with a coffee grinder to get a fine powder.

IR (KBr): 3428, 2928, 1611, 1430, 1159, 1083, 1020, 762, 711, 577 cm^{-1} .

EXAMPLE 5

Preparation of a carboxymethylstarch, crosslinked with divinylsulfone (39.38%), compound 7.

5

2.0g (0.0123 mol) of wheat starch A (Supercell 1201-C, ADM/Ogilvie) was suspended in 40 ml of deionized water. Under stirring, 3.5 ml 30% NaOH (0.0263 mol, 2.1eq.) was added dropwise and the solution stirred at room temperature for 1 hour. Chloroacetic acid (1.16 g, 0.0123 mol, 1eq), dissolved in 10 ml of deionized water and neutralized with 1.6 ml 30% NaOH (0.0123 mol, 1 eq.) was added dropwise and the reaction mixture was heated at 70°C for 24 hours. At room temperature, 0.784g (39.38% weight %) of divinylsulfone dissolved in 10ml acetone, was added dropwise and the solution was stirred for 2 hours. The polymer was precipitated with 100 ml of methanol, triturated in a blender, washed with 3 portions of 60 ml methanol, filtered and dry at 60°C for 16 hours to give 2.35g of a white solid. The solid was grinded with a coffee grinder to get a fine powder of compound 7.

10

15

IR (KBr): , 3427, 2927, 1603, 1415, 1321, 1154, 1083, 1025, 712, 578 cm⁻¹.

20

EXAMPLE 6

Preparation of a starch cicatronic half ester, crosslinked with divinylsulfone (0.62%), compound 9.

2.0g (0.0123 mol) of wheat starch A (Supercell 1201-C, ADM/Ogilvie) was suspended in 40 ml of deionized water. Under stirring, 5.0 ml 30% NaOH (0.0375 mol, 3eq..) was added dropwise and the solution stirred at room temperature for 1 hour. Citraconic anhydride (1.73g, 0.0133 mol, 1.1eq.), dissolved in 10ml acetone was added dropwise and the reaction mixture was stirred at room temperature for 2 hours. 12mg (0.62%) of divinylsulfone, dissolved in 10ml acetone, was added dropwise and the solution was stirred for 2 hours. The polymer was precipitated with 100 ml of methanol, triturated in a blender, washed with 3 portions of 60 ml methanol, filtered and dry at 60°C for 16 hours to give 1.92g of a white solid. The solid was grinded with a coffee grinder to get a fine powder of compound 9.

IR (KBr): 3399, 2929, 1715, 1644, 1571, 1446, 1407, 1276, 1153, 1081, 1026, 930, 853, 762, 710, 579, 530 cm^{-1} .

EXAMPLE 7

Preparation of carboxymethylstarch, crosslinked with dichlorotriethylene dioxyde (9.85%), compound 8.

2.0g (0.0123 mol) of wheat starch A (Supercell 1201-C, ADM/Ogilvie) was suspended in 40 ml of deionized water. Under stirring, 3.5 ml 30% NaOH (0.0263 mol, 2.1eq.) was added dropwise and the solution stirred at room temperature for 1 hour. Chloroacetic acid (1.16 g, 0.0123 mol, 1eq), dissolved in 10 ml of deionized water and neutralized with

1.6 ml 30% NaOH (0.0123 mol, 1 eq.) was added dropwise and the reaction mixture was heated at 70°C for 24 hours. At room temperature, 0.197g (9.85% weight %) of dichlorotriethylene dioxide dissolved in 10ml acetone, was added dropwise and the solution was heated at 70°C for 24 hours. The polymer was precipitated with 100 ml of methanol, triturated in a blender, washed with 3 portions of 60 ml methanol, filtered and dry at 60°C for 16 hours to give 1.95g of a white solid. The solid was grinded with a coffee grinder to get a fine powder of compound 8.

IR (KBr): 3408, 2929, 1607, 1423, 1327, 1158, 1083, 1021, 937, 849, 762, 710, 581, 530cm⁻¹.

EXAMPLE 8

Preparation of carboxymethylstarch, crosslinked with dichlorotriethylene dioxyde (40%), compound 8.

5 2.0g (0.0123 mol) of wheat starch A (Supercell 1201-C, ADM/Ogilvie) was suspended in 40 ml of deionized water. Under stirring, 3.5 ml 30% NaOH (0.0263 mol, 2.1eq.) was added dropwise and the solution stirred at room temperature for 1 hour. Chloroacetic acid (1.16 g, 0.0123 mol, 1eq), dissolved in 10 ml of deionized water and neutralized with
10 1.6 ml 30% NaOH (0.0123 mol, 1 eq.) was added dropwise and the reaction mixture was heated at 70°C for 24 hours. At room temperature, 0.80g (40 weight %) of dichlorotriethylene dioxide dissolved in 10ml acetone, was added dropwise and the solution was heated at 70°C for 24 hours. The polymer was precipitated with 100 ml of methanol, triturated in a blender, washed with 3 portions of 60 ml methanol, filtered and
15 dry at 60°C for 16 hours to give 2.06g of a white solid. The solid was grinded with a coffee grinder to get a fine powder of compound 8.

IR (KBr): 3404, 2928, 1607, 1424, 1327, 1155, 1084, 1020, 934, 849, 762, 710, 580, 530cm⁻¹.

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Claims:

1. Crosslinked polysaccharide (starch) obtained from polysaccharide (starch) by
crosslinking with at least one crosslinker selected in the group constituted by
substituted (preferably halogeno substituted) polyethylene glycols.
2. Polysaccharide (starch) crosslinked with a dichloropolyethylene oxide obtainable
by one of the processes described in the present application.
3. Polysaccharide (starch) crosslinked with a dichloropolyethylene oxide as
superabsorbent.
4. Use of the crosslinked polysaccharide according to claim 1 as biodegradable
superabsorbents and or/and as hypoallergenic superabsorbents.
5. Superabsorbent mixture comprising at least one crosslinked polysaccharide
according to claim 1.

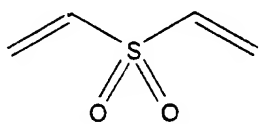


Figure 1

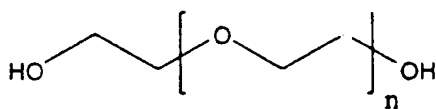


Figure 2

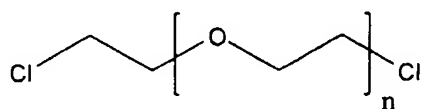


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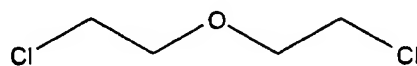


Figure 4



Figure 5

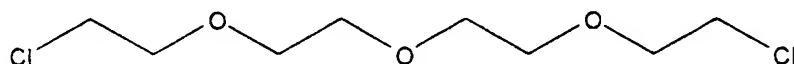
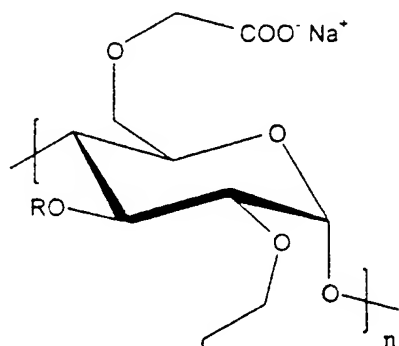


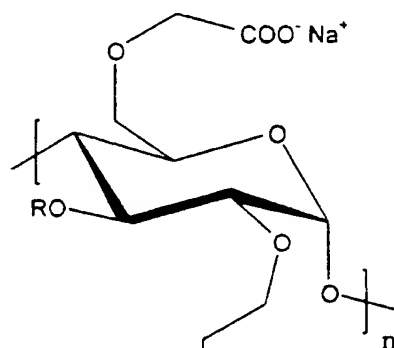
Figure 6



R = H, crosslink, carboxymethyl

Carboxymethylstarch

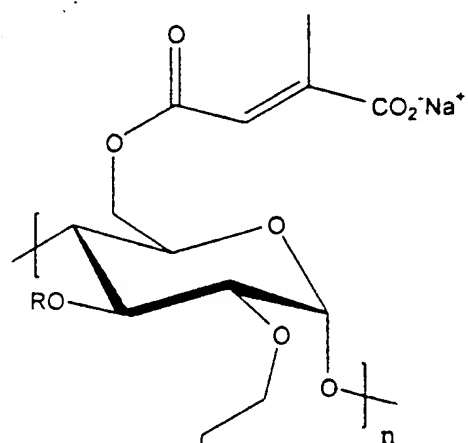
Figure 7



R = H, crosslink, carboxymethyl

Carboxymethylstarch

Figure 8



R = H, crosslink, citraconate

Citraconate-starch

Figure 9

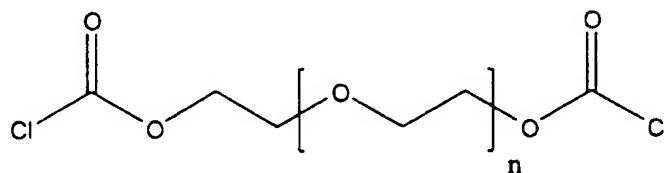


Figure 10

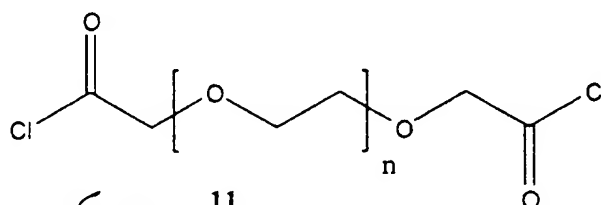


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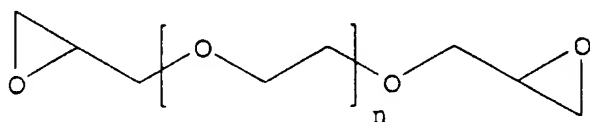
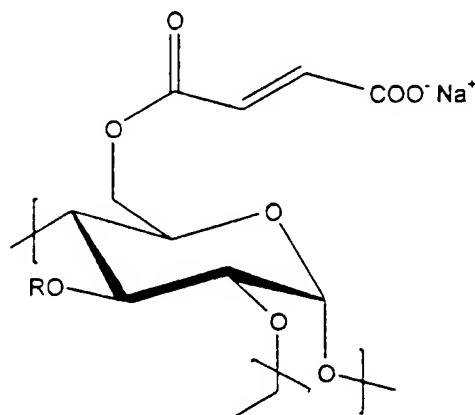


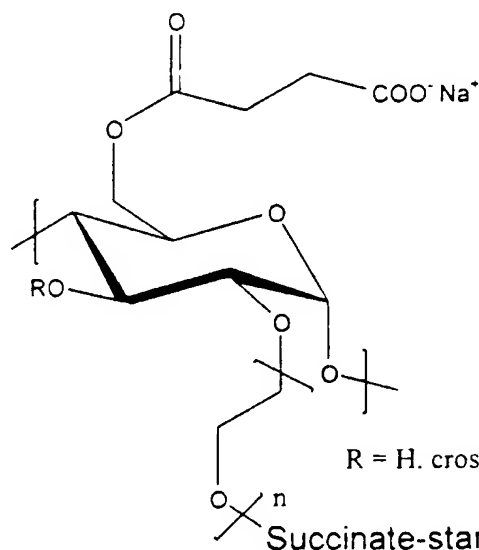
Figure 12



R = H, crosslink, maleate

Maleate-starch

Figure 13



R = H, crosslink, succinate

Succinate-starch

Figure 14

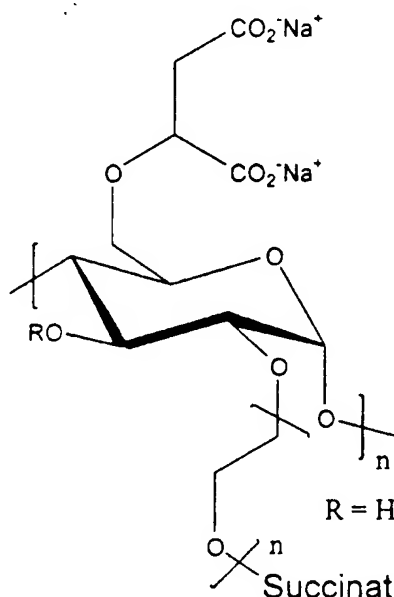


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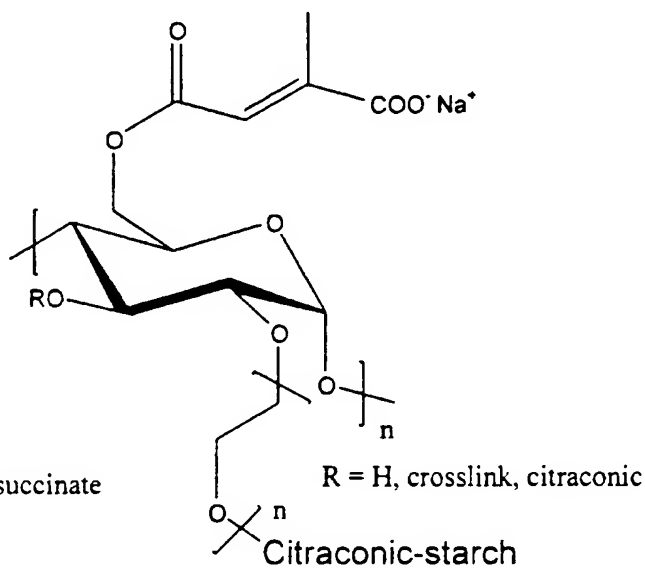


Figure 16

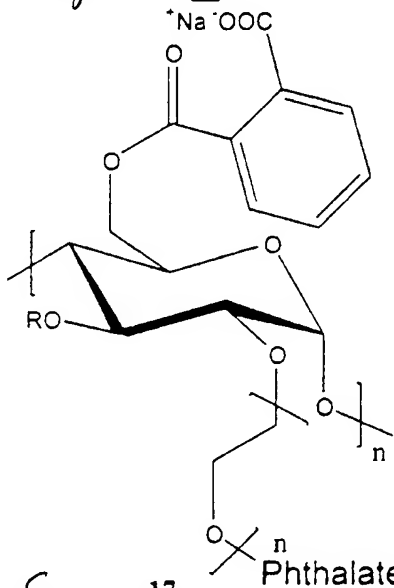


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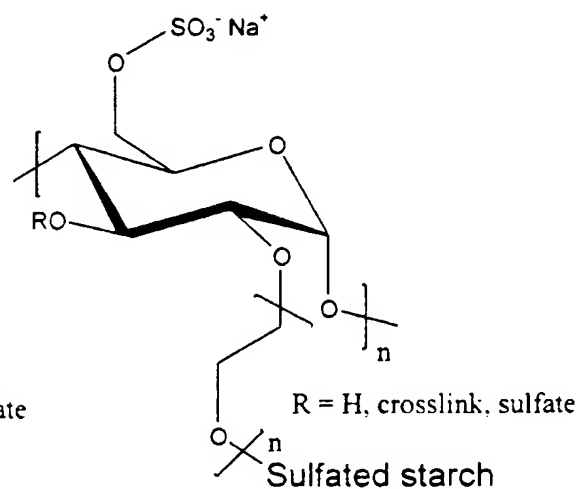


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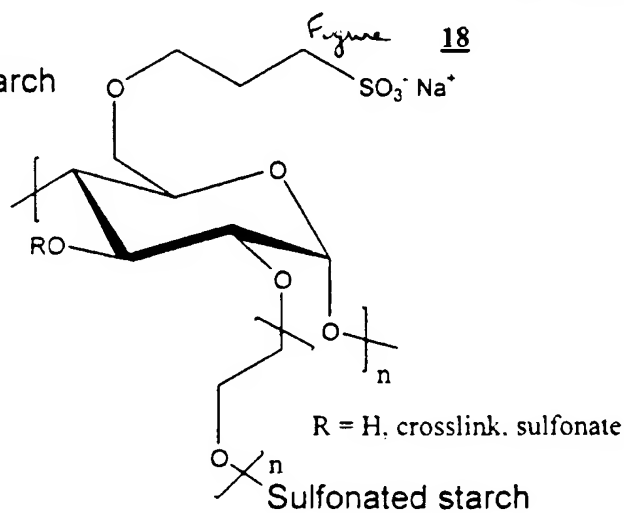


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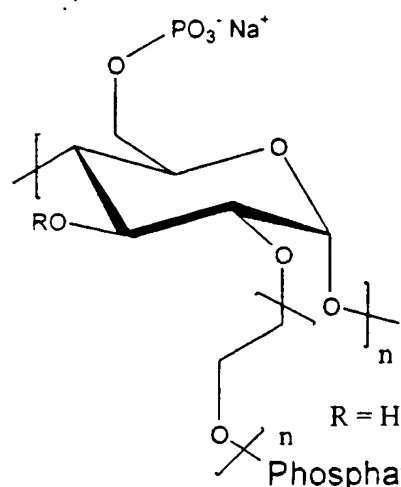


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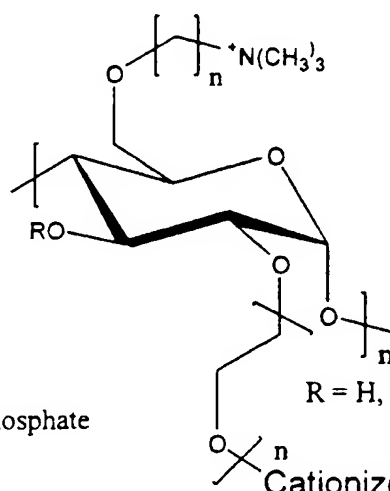


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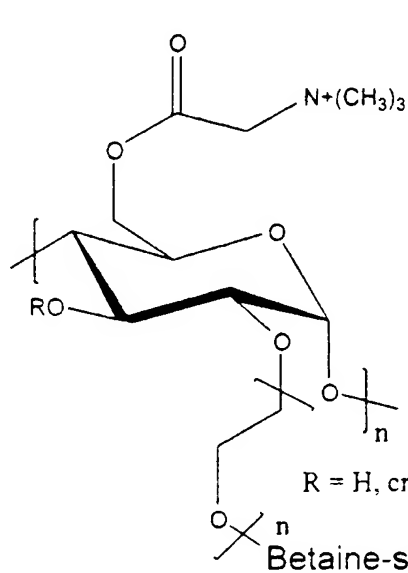


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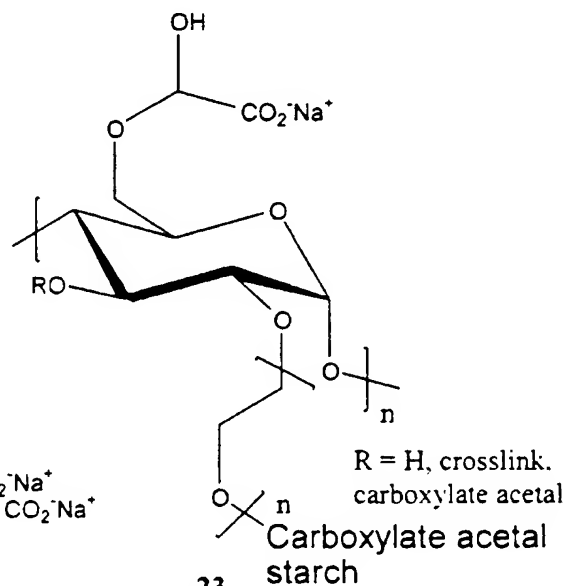


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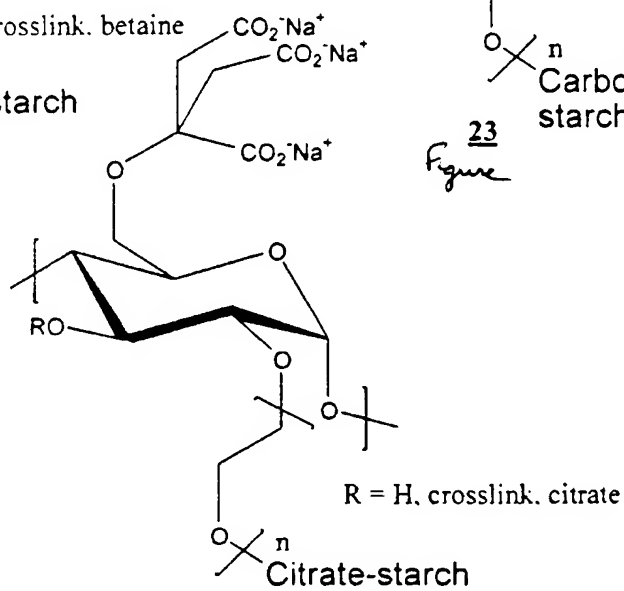


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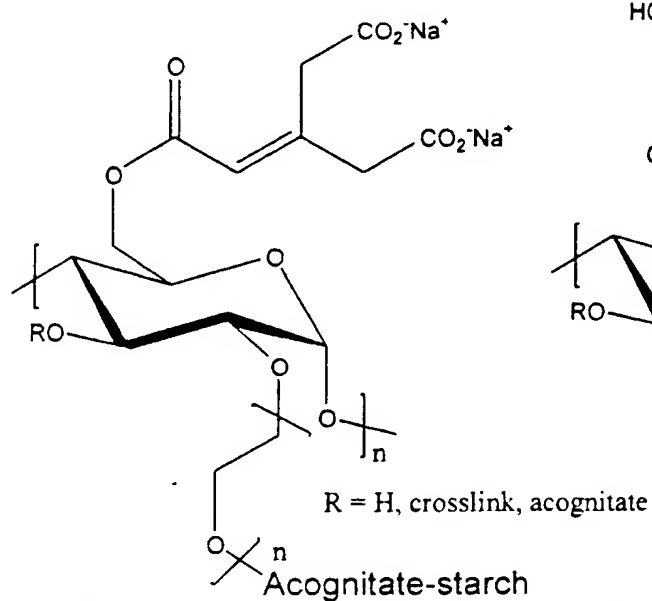


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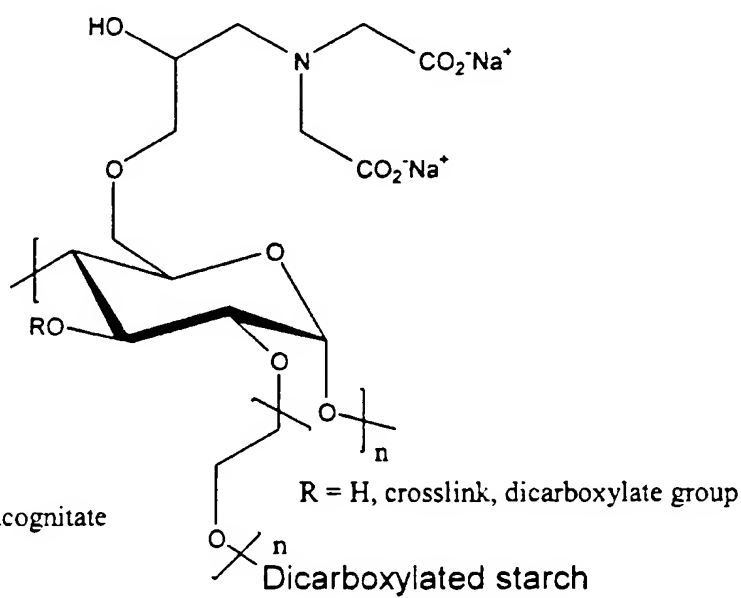


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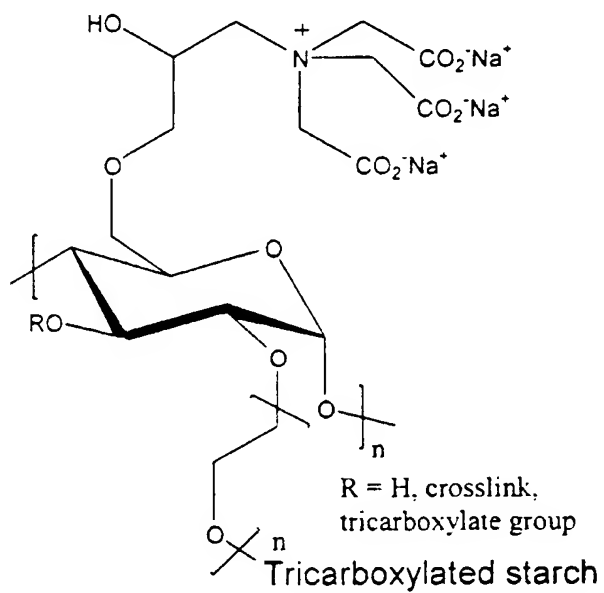


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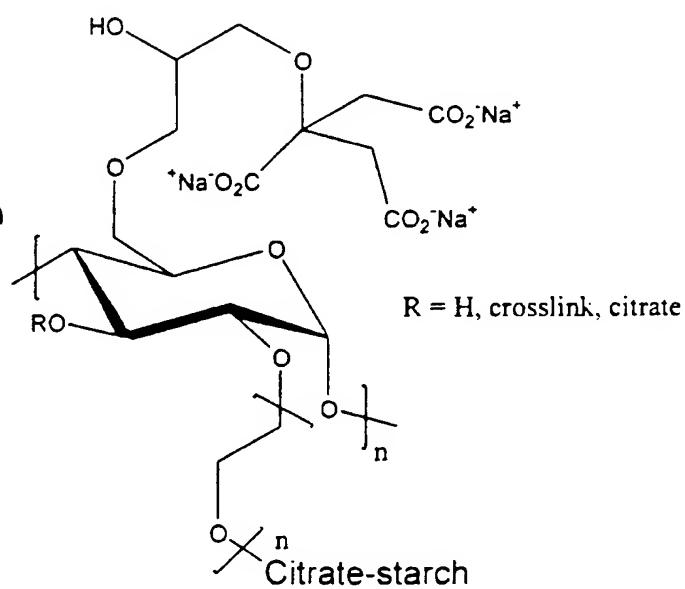


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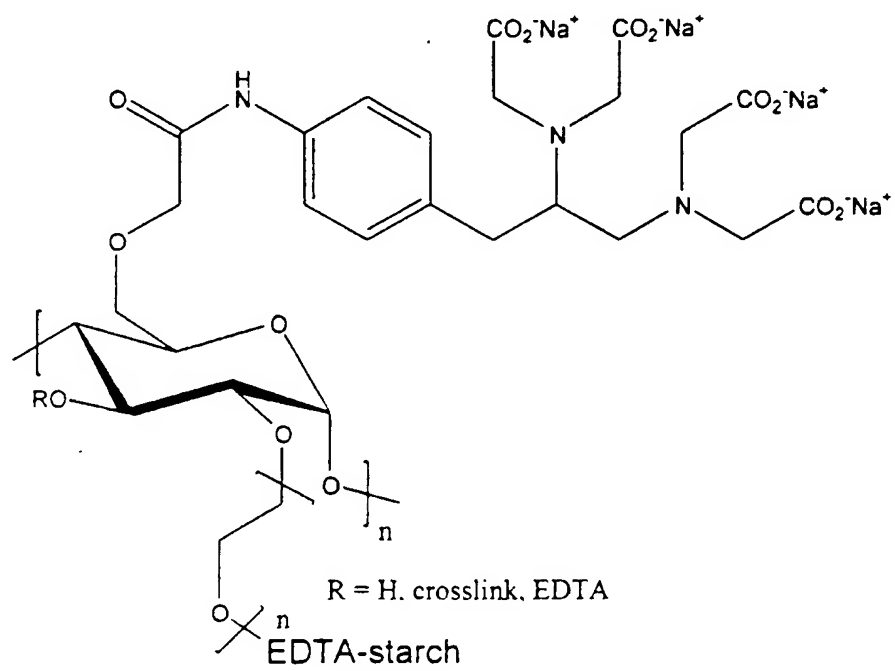


Figure 29

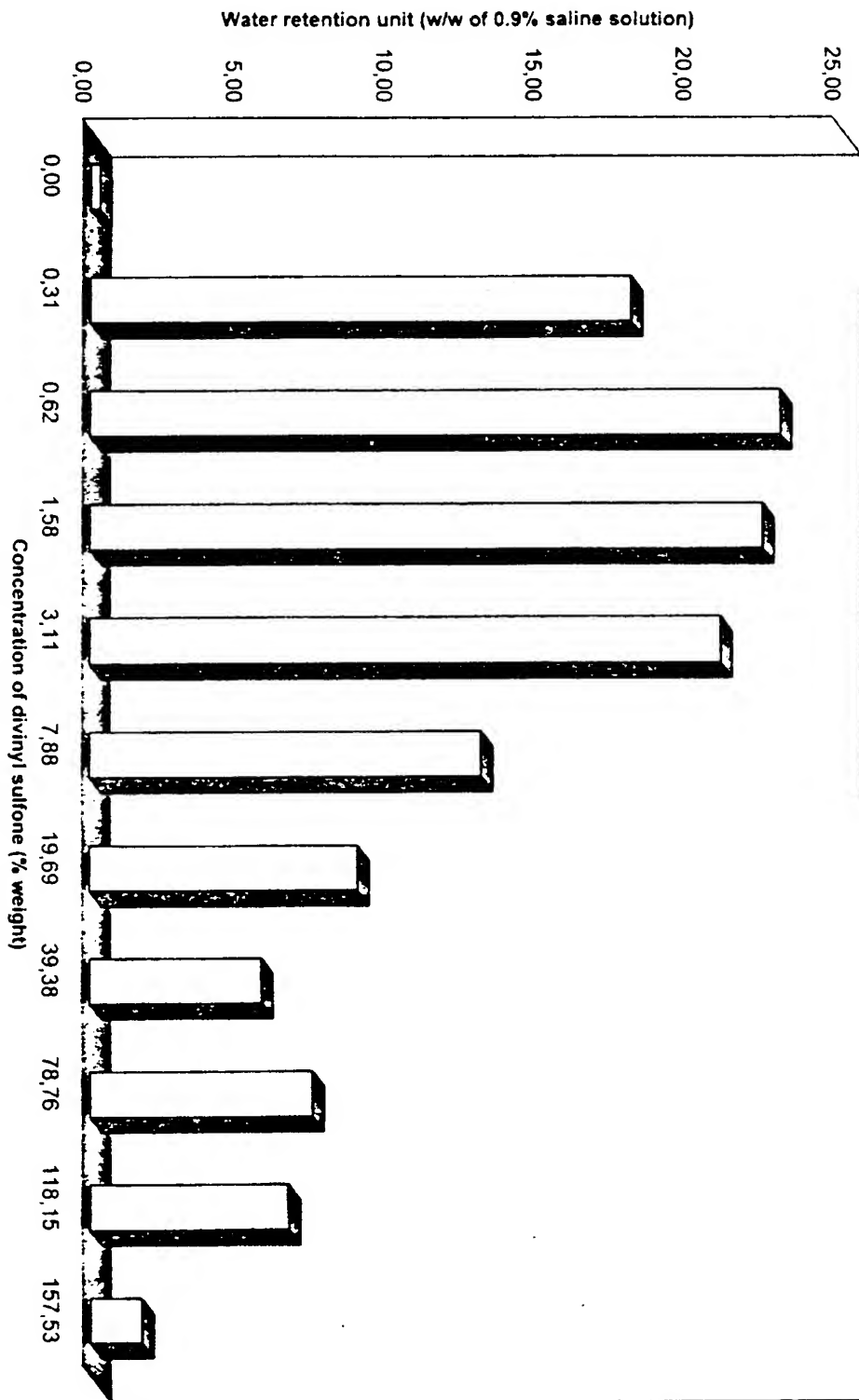


Figure 1. Effect of divinyl sulfone on water retention of carboxymethylstarch.

Figure 10

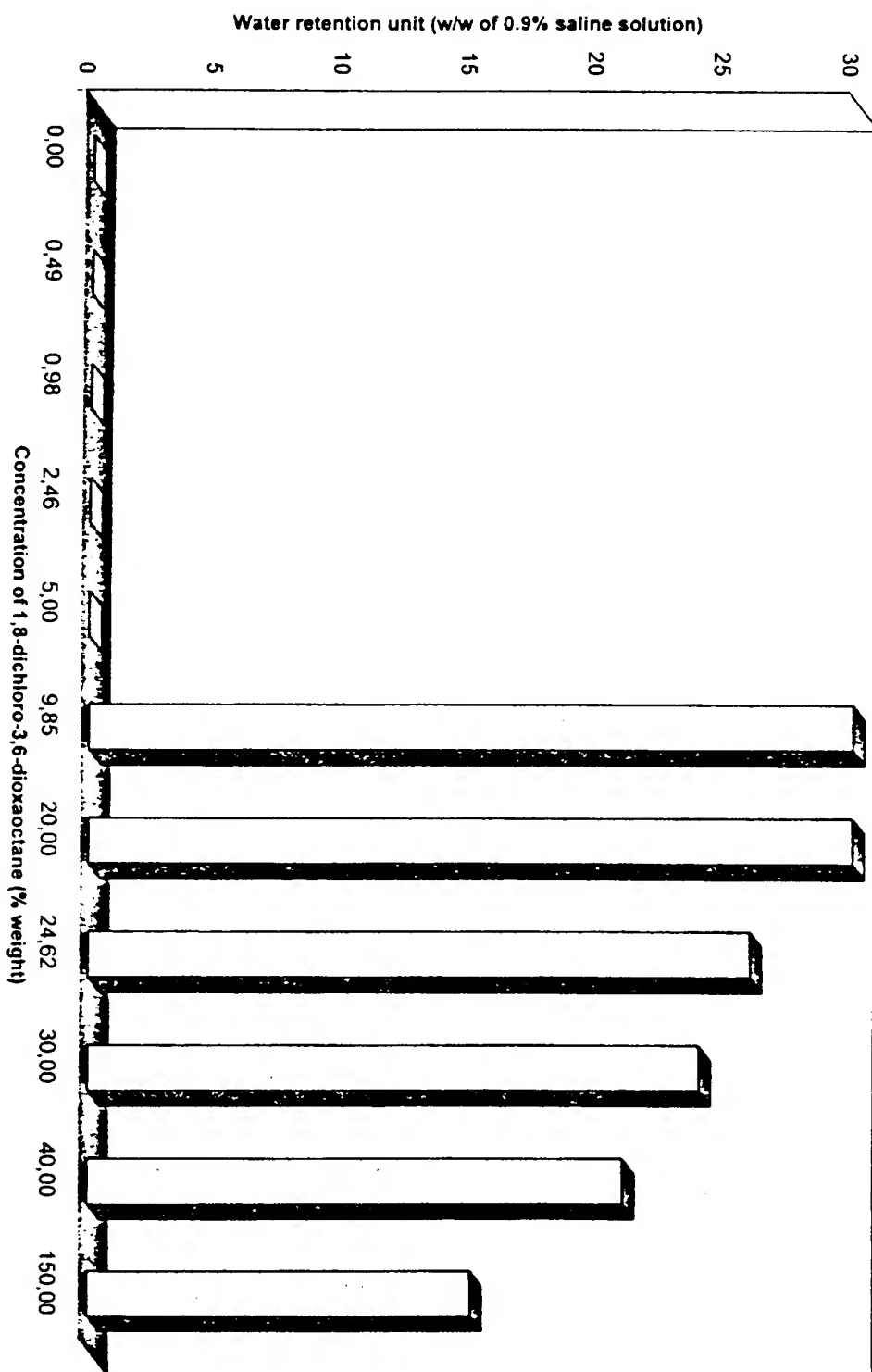


Figure 2. Effect of 1,8-dichloro-3,6-dioxaoctane on water retention of carboxymethylstarch.

Figure 3A

